THE WCRP/GEWEX SURFACE RADIATION BUDGET PROJECT RELEASE 2: AN ASSESSMENT OF SURFACE FLUXES AT 1 DEGREE RESOLUTION

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ABSTRACT

The U.S. National Aeronautics and Space Administration (NASA) based Surface Radiation Budget (SRB) Project in association with the World Climate Research Programme Global Energy and Water Cycle Experiment (WCRP/GEWEX) is preparing a new 1^o x 1^o horizontal resolution product for distribution scheduled for release in early 2001. The new release contains several significant upgrades from the previous version. This paper summarizes the most significant upgrades and presents validation results as an assessment of the new data set.

1. INTRODUCTION

The energy exchange at the surface is key to climate and climate processes. The radiative part of this exchange provides for the net absorption/emission of energy (solar and thermal infrared wavelengths) at the land surface and in the oceans. The Surface Radiation Budget project at NASA was therefore initiated to better quantify the radiative exchange at the Earth's surface over time. The project has been associated with the WCRP and now GEWEX to foster international collaboration in understanding these processes.

Here, we present an overview of the GEWEX SRB Release 2 data set that is being processed and archived at the NASA Langley Research Center Atmospheric Sciences Data Center (ASDC). Release 2 (R2) represents a significant upgrade from the v1.1 WCRP SRB Shortwave (SW) 4-year data set (Whitlock *et al.*, 1995) and NASA Langley 8 year data sets (Gupta *et al*., 1999). Among many upgrades the most important are: the addition of longwave (LW) flux algorithms, the increase of resolution from the 280 km x 280 km equal area grid system (hereafter, 280 km) to 1^ox1^o and the use of reanalysis meteorology from a data assimilation project. This R2 data set will provide SW and LW surface and top-of-atmosphere radiative fluxes for at least a 10-year period (1984-1993) for the globe. The fluxes will be produced at a variety of time resolutions including 3-hourly, daily, monthly and a monthly averaged 3-hourly.

Section 2 gives an overview of the upgrades to the input data sets. Section 3 gives a brief summary of the SW and LW algorithms and section 4 gives the results from comparison of the new data sets with surface observations. Finally, section 5 presents a brief summary. With planned archival in early 2001, the NASA WCRP/GEWEX SRB R2 data set will be the first observational surface radiation data set to span over a decade.

2. IMPROVEMENTS TO INPUT DATA SETS

2.1 ISCCP DX Processing

To achieve the higher resolution of 1^ox1^o, the International Satellite Cloud Climatology Project (ISCCP) DX pixel data set is used to build cloud statistics at each grid box. The ISCCP D series represents an upgrade over the C series used in the earlier SRB data sets (Rossow and Schiffer, 1999). Each pixel (4 km pixels, sampled to nominal 30 km spatial resolution) contains the cloud decision threshold and retrieval information as provided by ISCCP (Rossow *et al.*, 1996). Pixels from either a geo-synchronous or polar orbiting satellite are selected for each grid box and the statistics from these pixels are computed analogously to the procedures of ISCCP at 280 km.

Figure 1 gives two panels comparing the instantaneous cloud optical depth between the 280 km from ISCCP D1 and the higher 1^o resolution clouds averaged from ISCCP DX for 11 October 1986 at 18UT. Figure 2 shows the D1 and DX 3-hourly optical depth histogram distributions for the entire month of October 1986. The higher resolution changes the statistical distribution of clouds. The peaks of each distribution are located at nearly the same optical depth, but the DX peak frequency is significantly less. The means are within 4%, but the wider distribution gives more thin and thick clouds at the higher resolution than at the coarser resolution. The ramifications of these changes are still being studied.

2.2 Reanalysis Meteorology

Unlike 280 km ISCCP C1 and D1 data sets, the TIROS Operational Vertical Sounder (TOVS) meteorology is not included in the ISCCP DX pixel data sets. To provide the necessary meteorological profile information including temperature and humidity, a global reanalysis is used. A

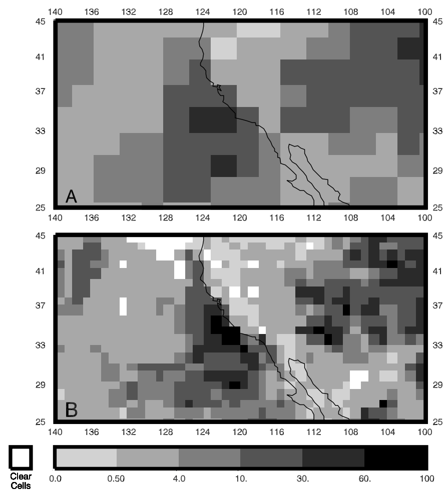

Figure 1: Optical depths maps over the U.S. on 11 Oct. 1986, 18 UT from both the ISCCP D1 at 280 km (A) and the new DX based 1 degree (B) data sets.

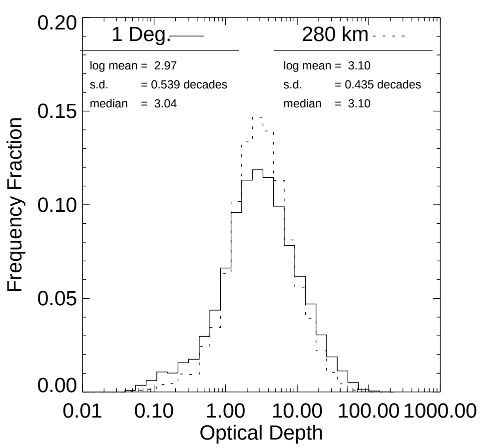

Figure 2: Optical depth histograms composited for October 1986 for the ISCCP D1 (280 km) and the new DX (1 degree) data sets.

reanalysis provides a better representation of the diurnal cycle of temperature and humidity relative to the TOVS soundings that are mainly given at once per day. Presently, the Goddard Earth Observing System (GEOS) v.1 reanalysis provided by the Data Assimilation Office (DAO) of NASA's Goddard Space Flight Center is used to provide this information. Sensitivity testing and comparisons to ECMWF and the NASA Water Vapor Project (NVAP) revealed that the problems with GEOS-1 reanalysis do not dominate the differences found in comparison to surface observations.

2.3 Ancillary Inputs

In addition to the reanalysis, other new data inputs at higher resolution have been included. The most important of these is the 1.25^{o} longitude x 1^{o} latitude resolution column ozone from the measurements of the Total Ozone Mapping Spectrometer (TOMS). High resolution surface type classification maps are also being included. These maps were used to infer an estimate of the global surface thermal infrared emissivity. The spectral values of surface emissivity are currently static and based primarily on laboratory measurements of different organic and inorganic surface materials (i.e., leaves, dust, ice, etc.) (Wilber *et al.*, 1999).

3. GEWEX SRB ALGORITHMS

3.1 SW Algorithms

The shortwave algorithms included in the SRB R2 at 1 degree resolution are essentially the same as documented in Whitlock *et al.* (1995). The official GEWEX SW algorithm is that of Pinker and Laszlo (1992). This algorithm computes a broadband solar flux for each time step. The algorithm uses a two-stream delta-Eddington model to map broadband reflected fluxes at the Top-of-Atmosphere (TOA) to transmitted fluxes at the surface. The reflected fluxes at TOA are computed using narrow band to broadband relationships on the visible radiances and angular distribution models (ADMs) from the Earth Radiation Budget Experiment (ERBE). The model has been updated with new water vapor parameterizations and averaging techniques.

The GEWEX SW Quality Check (QC) algorithm is that described in Darnell *et al*. (1992) although it has been upgraded to include better gaseous absorption and daily average weighting parameterizations. This model a physical-empirical surface insolation model since it employs several empirical and parametric relationships to account for various scattering and absorptive processes in the atmosphere. The central feature of the scheme is an empirical fit between a cloud transmittance and fractional radiance between brightest and darkest pixels in a grid box during a given day. This provides a method of estimating cloud transmittance independently from the absolute satellite calibration. The algorithm was primarily designed to give daily averaged solar insolation and uses surface albedos derived from corrected ERBE measurements. TOA fluxes are not computed with this scheme.

3.2 LW Algorithms

In the longwave, a new GEWEX LW algorithm is introduced. This algorithm uses the Fu *et al*. (1997) infrared radiative transfer model. This radiative transfer model is the same model used in the Surface and Atmospheric Radiative Budget (SARB) flux computations that are part of the Clouds and the Earth's Radiant Energy Systems (CERES) processing system. The model uses correlated-k distributions in 12 wavelength bands to account for gaseous absorption and treats longwave scattering requiring the specification of cloud and aerosol optical properties. The model also treats non-black surfaces and will use as input surface emissivity maps (Wilber *et al*., 1999). Cloud bases are prescribed by using cloud top temperatures to infer cloud top level and a cloud thickness (in mb) depending on latitude and height. Random cloud overlap is assumed to better estimate the distribution of cloud base in a particular grid box. The algorithm is used to estimate both TOA and surface fluxes.

The GEWEX LW QC algorithm is the same as described in Gupta *et al*. (1992). This algorithm uses broadband parameterizations of narrow band (10 cm^{-1}) radiative transfer calculations as a function of water vapor and temperature to compute a clear-sky flux given the meteorological profile of the grid box. The model uses cloud fraction and the cloud top temperatures to prescribe the effects of clouds on the clear-sky flux using the same assumptions about cloud thickness mentioned above. TOA fluxes are currently not computed with this algorithm, but the model does allow for non-black surface emittances.

4. VALIDATION AND ASSESSMENT

To upgrade the GEWEX SRB to 1^o resolution, the input data sets and SRB algorithms had to be recoded and implemented into a new processing system. To test the algorithm upgrades and processing system, a set of 10 test months was processed including all the mid-seasonal months for 1986 and 1992. Here, we compare R2 flux estimates to measurements of surface SW and LW fluxes providing an assessment of data quality obtained in 1986 and 1992.

Table 1 presents the monthly averaged differences between R2 SW surface flux estimates and measurements for all sites and sites grouped according to each major continent for January and July of 1986. These measurements are archived at the World Radiation Data Centre (WRDC) in St. Petersburg, Russia and are used in the Global Energy Balance Archive (GEBA). Although the continent of Europe is best represented in the WRDC database, there are enough SW measurement sites available on each continent to study the differences based upon region. Since water vapor, cloudiness, aerosol distributions, and surface albedos change on a regional basis, this database will be useful for studying the dependence of errors as a function of many different variables. The R2 SW fluxes show a general decrease in the average difference (or bias) relative to the 280 km ISCCP C1 based data set. The RMS differences remain nearly the same. Subsequent analysis has shown that the general decrease in bias is due mostly to the differences between the ISCCP C and D series data sets. Region by region, bias differences in R2 show a systematic decrease and now are usually much less than 5% of the observed insolation. As the lone exception, the bias differences for the Central and South America sites are dramatically improved but are still about 8%. RMS differences are generally within a few W m^{-2} of the v1.1 data set.

Table 1: Monthly average and RMS differences between the solar insolation estimates and measurements for v1.1 SRB (v1.1, 280 km) and R2 (R2, 1^o) data sets in 1986.

Continental Region	Month	Mean Obs. Flux	Average Difference (Est. – Obs.)		R.M.S. Difference (Est. – Obs.)	
			v1.1	R2	v1.1	R2
All	Jan.	110.4	8.4	2.9	21.5	19.0
	Jul.	218.1	9.8	0.9	28.9	28.5
North America	Jan.	48.5	-1.4	-0.6	9.9	8.1
	Jul.	229.5	3.4	-10.0	16.1	19.5
Europe	Jan.	51.4	4.5	3.0	10.6	11.7
	Jul.	237.5	3.0	-5.2	28.0	29.0
Asia	Jan.	111.7	13.4	6.0	21.3	20.0
	Jul.	204.6	25.5	12.3	24.2	30.0
Cent./S. America	Jan.	193.9	26.4	14.8	37.2	32.7
	Jul.	204.6	22.6	14.0	36.6	33.0
Africa	Jan.	220.6	13.7	1.3	33.9	32.2
	Jul.	222.3	12.4	6.8	35.0	34.7
Australia	Jan.	292.3	8.2	-8.2	20.2	28.1
	Jul.	116.6	9.4	5.0	12.8	13.6

Figure 3 gives the SW and LW flux estimates versus Baseline Surface Radiation Network (BSRN) measurements for all available sites and 5 months (Jan, Apr., Jun., Jul., Oct.) in 1992. The top two panels present the comparison of the daily averaged estimated and measured fluxes and the bottom two panels present the monthly averages. The RMS differences (est. – obs.) between the daily and monthly averages decrease by a factor of 2 for the SW, but only about 33% for the LW. This is attributable to the higher degree of variability in the SW that is more difficult to replicate than in the LW. However, the RMS differences between SW and LW are comparable on the monthly averaged basis. The biases relative to both SW and LW are within +/- 4 W m^{-2}. The BSRN measurements represent a significant upgrade in the quality of the surface radiation measurements including surface LW measurements which are rare before 1992. The agreement shown here between these SW measurements and R2 SW fluxes is comparable if not better than the historical measurements.

Figure 4 gives the monthly averaged solar diurnal cycles for Bermuda in 1992. The integrated % difference is the difference between the integral of the surface measurements and the SRB flux measurements. Since BSRN measurements are hourly, these data are used to evaluate the ability of the 3-hourly flux data to estimate the diurnal cycle. The results indicate that the solar cycle is well estimated at this site, despite its island location. BSRN, SURFRad and ARM IOP networks will provide crucial surface validation points for flux estimates after 1992.

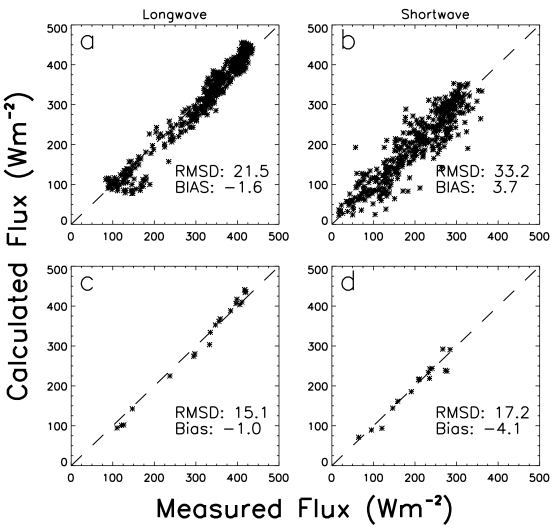

Figure 3: Comparisons between GEWEX SRB R2 fluxes and BSRN measurements for 5 months in 1992 for daily averaged LW (a) and SW (b) and monthly averaged LW (c) and SW (d) fluxes.

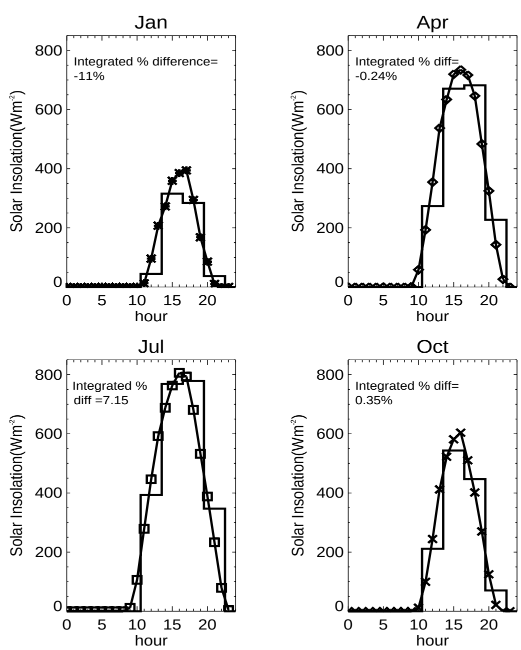

Figure 4: Monthly averaged solar insolation diurnal cycles for Bermuda in 1992 for SRB (3-hourly) and BSRN (hourly).

5. SUMMARY

A new version of the GEWEX SRB climatology is being prepared for archival. The new version has improved algorithms, 1° spatial and 3 hourly temporal input/output resolution using ISCCP and GEOS-1, and improved surface properties including spectral surface emissivity. Comparisons to WRDC measurements in 1986 give mean differences that are systematically reduced relative to the previous SRB version. SW RMS differences remain about the same. Comparisons of R2 fluxes to all available BSRN sites in 1992 for daily, monthly, and monthly averaged diurnal cycle show very good agreement. Future work will focus upon validation, processing and archival. Processing information will be made available on the GEWEX SRB homepage:
http://srb-swlw.larc.nasa.gov/Pilot_homepage.html

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